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(54) SEMICONDUCTOR ARRANGEMENTS AND COOLING MEANS THEREFOR

(71) We, SIEMENS AKTIENGESELLSCHAFT, a German Company, of Berlin and Munich, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to semiconductor arrangements and cooling means therefor, for example to cooled arrangements in which three or more pairs of semiconductor disc-form components current one after another in cyclically repeated order, when the arrangement is in use, and in which the semiconductor components are disposed under pressure between parallel contact bodies.

Thyristor current converters have been proposed in which thyristors are screwed with their housing into cooling bodies (screw-type thyristors). The coolant employed is mainly air. In another previously-proposed thyristor current converter, the thyristors are accommodated in disc-form housings which are disposed in column form, in series or in parallel with one another, with the interposition of cooling boxes having cooling liquid supply and discharge ducts and electrical terminal connecting members, and are held in position by screw bolts with the interposition of pressure plates. These constructions involve a complex arrangement both of the ducts for the cooling liquid and of the electrical terminal connecting members, and can thus be bulky.

Similar constructions are known in the case of rectifier arrangements. Here again, difficulties can arise in the guiding of the cooling liquid and in the arrangement of electrical terminal connecting members.

According to the present invention there is provided a semiconductor arrangement including a plurality of pairs of semiconductor components held between first and second electrically-conductive wall portions of the arrangement for conducting electrical current between those two wall portions, the two semiconductor components of each pair being in axial alignment with one another and having sandwiched between them an inner contact plate assembly providing an electrical connection between the two semiconductor components, respective first semiconductor components of the said pairs having respective terminal connecting parts which are connected electrically in common by being in contact with the said first electrically-conductive wall portion, the other semiconductor components of the said pairs having respective terminal connecting parts which are connected electrically in common by being in contact with the said second electrically-conductive wall portion, and the said first and second wall portions being arranged to provide respective opposed bounding surfaces of a coolant space therebetween, for containing an electrically insulating coolant, so that the first and second wall portions can participate in the dissipation of heat from the semiconductor components when the arrangement is in use, the said pairs of semiconductor components, with their respective contact plate assemblies being disposed in the said coolant space.

An embodiment of the present invention can be constructed so as to provide, in a reasonably simple and practical form, electrical and thermal connections between three or more pairs of semiconductor components, and also coolant guiding means, in an arrangement which is desirably small in overall size and weight. Opposing wall portions of such an arrangement can be parallel contact bodies which are at the same time constructed as cooling bodies, which are in direct contact with the electrically insulating coolant, and as electrical connecting bodies between the semiconductor components, the semiconductor components being so arranged that electrical terminal

connecting faces thereof lie at equal potential on like electrical connecting bodies. In this way, the number of coolant connections and the number of separate electrical circuit connections between individual semiconductor components can be kept small, with consequent advantages from the point of view of mechanical and electrical operating reliability. At the same time, a desirably compact self-contained form of construction of reasonably low weight, can be obtained.

For a better understanding of the present invention, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 is a circuit diagram of a converter arrangement,

Figures 2a and 2b show a longitudinal sectional view and a cross-sectional view respectively of a semiconductor arrangement embodying the present invention, having the circuit of Figure 1,

Figure 3a is a diagram of a circuit which can provide an output signal having a frequency which is a multiple of the input frequency;

Figures 3b and 3c show a cross-sectional view and a longitudinal sectional view respectively of a second semiconductor arrangement embodying the present invention, having the circuit of Figure 3a,

Figure 4a shows a vertical sectional view of a third semiconductor arrangement embodying the present invention,

Figure 4b shows an end view of the arrangement of Figure 4a, and

Figure 4c shows a vertical sectional view of part of a fourth semiconductor arrangement embodying the present invention.

Figure 1 shows a converter circuit, which can be used either to convert alternating current to direct current or to convert direct current to alternating current, the circuit requiring a minimum of twelve controllable semiconductor components (thyristors) 1 to 12. The satisfactory arrangement of such a large number of thyristors between parallel contact plates has been regarded as difficult hitherto because high requirements must be met in regard to the plano-parallel construction of the contact faces of the semiconductor components, and the contact plates, in order to ensure a good transfer of current and heat.

As is illustrated in Figures 2a and 2b, these difficulties can be obviated by disposing within the arrangement resilient members 23 which produce a pressure from the inside. Preferably, an inner contact plate assembly (for example 15a), connected to one alternating-voltage pole, is formed of two component plates (15a1, 15a2) between which a helical spring is provided as resilient member 23. These parts form with two semiconductor components (1, 2), which are in axial alignment with one another, a sandwich-form set which, together with further sets disposed with parallel axes, is gripped between the two outer contact plates 13 and 14 to form a unitary arrangement. Thus it will be appreciated that semiconductor components 1, 3, 5, 7, 9 and 11 have respective terminal connecting parts which are connected electrically in common by being in contact with contact plate 13, and that semiconductor components 2, 4, 6, 8, 10 and 12 have respective terminal connecting parts which are connected in common by being in contact with contact plate 14. Insulated walls 22 (Figure 2b) are disposed between the outer contact plates 13 and 14. The outer contact plates are then held together by rigid and insulating retaining clips 29. In this way, differences in the plano-parallel positions of the contact faces are balanced out by the resilient members 23. Therefore, semiconductor components and contact plates having relatively large manufacturing tolerances may be employed. An electrically conductive copper-clad steel mesh shroud or the like is advantageously provided in association with each resilient member 23. In this way, an electric and resilient connection is simultaneously established between the divided component plates 15a1 and 15a2 at like potential. Component plates 15b1 and 15b2 are also connected to the same alternating-voltage pole and are elastically connected to the component plate 15a1 by an electric connecting member 21. The remaining thyristors are mounted in a similar pattern.

The insulated walls 22 are disposed between the two outer contact plates (Figure 2b), so that the space between those contact plates 13 and 14 can serve as an inner cooling channel. In this way, the component plates 15 need not be provided with cooling channels, cooling liquid connections between the component plates (for example 15a1, 15b1) being rendered unnecessary. Particularly intensive cooling can be achieved in this way with simple means. Electrically insulating coolant flows through the channels of the outer contact plates 13 and 14, and through the inner cooling channel, in the direction of arrows 18. For example, the thyristor 1 gives up its loss heat through the contact faces of the disc cell 20 (a semiconductor tablet in a disc-form housing) to the contact plates 13 and 15a1 and additionally through the peripheral surface of the disc cell 20 directly to the coolant. The other thyristors are similarly cooled.

There is shown in Figure 3a a circuit, having thirty-six thyristors, which circuit can provide an output signal having

a frequency which is a multiple of the input frequency. The mechanical construction as illustrated in Figures 3*b* and 3*c* is similar in principle to that described with reference to Figures 2*a* and 2*b*. In each instance, there is formed of two tablet-form semiconductor components (for example, 1 and 2) with the interposition of a resilient member 23 and two contact plates (15*a*1 and 15*a*2) a sandwich-form set, the semiconductor components 1 to 12 being in this case in direct contact with the outer contact plates 13 and 14. This design has the advantage that the peripheral surfaces of the semiconductor components are directly washed by coolant. Hence, thermal resistances associated with the disc cells 20 are avoided and a substantially better dissipation of the loss heat is thus achieved. Moreover, the weight of the frequency changing circuit structure is reduced owing to the omission of the disc cell structures.

If the frequency changing circuit is so connected to the alternating-voltage source — as shown in Figure 3*a* — that neutral conductors Mp of an alternating-voltage output system Ra, Sa, Ta can be connected together, then all the thyristors in which the anode and the cathode have the same potential as the neutral conductor Mp may with advantage be mounted on a common contact plate 14 as in Figures 3*b* and 3*c*. In the present case, eighteen tablet-form semiconductor components are mounted directly on the outer contact plate 14. An opposite outer contact-plate structure 13 is provided with cooling fins 24 and is formed of three component plates 13*a*, 13*b*, 13*c* insulated from one another by insulating members 13*d* and connected to the alternating-voltage outputs Ra, Sa, and Ta respectively. The arrangement is provided with lateral walls 22 so that the semiconductor components, the inner contact plates 15*a*, and the resilient members 23, lie in an entirely enclosed space. This space is filled with electrically insulating cooling liquid.

If, in accordance with another development, coolant supply and discharge ducts 25, 26 (shown in chain lines in Figure 3*c*) are connected to the arrangement as in Figure 22*a* b, no intermediate connections need be made for the guiding of the cooling liquid as in one previously-proposed direct frequency changing circuit structure, constructed from individual units, in which seventy-two electrical connections and intermediate connections for the guiding of the coolant are necessary. In the illustrated way, both the volume and the weight can be kept particularly low as compared with the previously-proposed arrangement.

In addition, a closed unit renders possible the application of boiling cooling, in which cooling liquid is heated to boiling point by the loss heat of the thyristors. Boiling cooling produces a particularly good heat dissipation. In this case, it is possible by the arrangement of the thyristors in an embodiment of the invention to dispose the liquid in a cooling liquid space between two outer contact bodies (such as 13 and 14). Moreover, the boiling cooling may be employed alone or in combination with a throughflow cooling.

The development illustrated in Figures 3*b* and 3*c*, in which one outer contact body 13 or both may be provided with cooling fins 24, is particularly suitable for a closed boiling cooling system, where the arrangement is washed on the outside by air or another coolant.

An embodiment of the invention can also be employed where a semiconductor arrangement forms a unit with an alternating-voltage source by which it is fed. Figure 4*a* shows a transformer 27 having a sequentially connected frequency changing circuit according to Figure 3*a*. A tank wall 14*a* of a transformer 27 serves both as a heat-conducting contact plate and as an electrical connecting bar for the common neutral point Mp of the circuit of Figure 3*a*. Terminal connecting conductors 28 of the secondary windings of the transformer 27 extend through insulating members 14*d* in the wall 14*a*. The arrangement of the thyristors 1 to 12, of the inner contact plates 15*a*1, 15*a*2, etc. and of the resilient members 23 is similar to that already shown in the preceding Figures. The second outer contact plate 13 is formed of component plates 13*a*, 13*b*, 13*c* insulated from one another by insulating members 13*d*, the said plates constituting the alternating-voltage outputs Ra, Sa, Ta (see the end view of Figure 4*b*).

It will be assumed that the transformer tank is filled with oil as coolant. There is denoted by 22*a* the surface of the coolant. The space in which the thyristors are situated is also constructed as a tank. Oil also flows through an aperture 30 into the tank with the thyristors and directly surrounds and cools the thyristors. If the oil is not sufficient to absorb the loss heat, the component plates 13*a*, 13*b*, 13*c* may be additionally ventilated through fins 24. Such incorporation of the frequency changing circuit structure or its attachment to the alternating-voltage source has *inter alia* the advantage that, in the construction of the circuit arrangement, the wall 14*a* which is already present is used as a cooling and connecting member, and the alternating-voltage source and the thyristor arrangement have the same coolant circuit and the same cooling liquid may thus be employed for both arrangements.

As an alternative, Figure 4*c* shows how

the thyristor arrangement can be mounted, not directly on the wall 14*a* of the energy source, but on a separate contact plate 14, and the terminal connecting members of the arrangement can then be so constructed that the whole arrangement, or parts thereof, can be separately plugged onto the alternating-voltage source through an insulating plate 14*e* (Figure 4*c*). In this way, it is possible for the whole thyristor arrangement or parts thereof to be replaced in a very short time. In the illustrated example there are disposed in the wall 14*a* plug sockets 31 which are insulated by insulating members 14*d* and which form the three-phase current terminal connecting members. Plug pins 32 of the thyristor arrangement engage in the said plug sockets 31. To form a common coolant circuit, the transformer tank is formed with at least one aperture 30 into which there can be plugged a branch tube 33 which is connected to the coolant space of the thyristor arrangement. The terminal connection can be so formed that the branch tube 33 and the aperture 30 in the transformer tank open only when the thyristor arrangement is plugged on.

WHAT WE CLAIM IS:—

1. A semiconductor arrangement including a plurality of pairs of semiconductor components held between first and second electrically-conductive wall portions of the arrangement for conducting electrical current between those two wall portions, the two semiconductor components of each pair being in axial alignment with one another and having sandwiched between them an inner contact plate assembly providing an electrical connection between the two semiconductor components, respective first semiconductor components of the said pairs having respective terminal connecting parts which are connected electrically in common by being in contact with the said first electrically-conductive wall portion, the other semiconductor components of the said pairs having respective terminal connecting parts which are connected electrically in common by being in contact with the said second electrically-conductive wall portion, and the said first and second wall portions being arranged to provide respective opposed bounding surfaces of a coolant space therebetween, for containing an electrically insulating coolant, so that the first and second wall portions can participate in the dissipation of heat from the semiconductor components when the arrangement is in use, the said pairs of semiconductor components, with their respective contact plate assemblies, being disposed in the said coolant space.

2. An arrangement as claimed in claim 1, wherein the said pairs of semiconductor components are three in number and are arranged and connected so as to conduct electrical current one after another, in a cyclically repeated order, when the arrangement is in use.

3. An arrangement as claimed in claim 1 or 2, wherein the said semiconductor components are disc-shaped.

4. An arrangement as claimed in claim 1, 2, or 3, wherein the said first and second wall portions extend parallel to one another.

5. An arrangement as claimed in any preceding claim, wherein the said inner contact plate assemblies include respective resilient members which maintain pressure between the two semiconductor components of each pair, on the one hand, and the two electrically-conductive wall portions, contacted respectively by those components, on the other hand.

6. An arrangement as claimed in claim 5, wherein the said resilient members are provided with copper-clad steel mesh shrouds for assisting in the conduction of electrical current by way of the inner contact plate assemblies.

7. An arrangement as claimed in any preceding claim, wherein the semiconductor components are disc-cells, including respective semiconductor bodies, whose edge regions are washed by the coolant when the arrangement is in use.

8. An arrangement as claimed in any one of claims 1 to 6, wherein the semiconductor components are semiconductor tablets each of which has respective electrodes at its parallel main faces, some of which electrodes constitute the said terminal connecting parts, the peripheries of the semiconductor tablets being washed by the coolant when the arrangement is in use.

9. An arrangement as claimed in any preceding claim, adapted to have its loss heat dissipated, when the arrangement is in use, at least partially through boiling of the coolant.

10. An arrangement as claimed in any preceding claim, provided with plug-type electrical terminal connecting members whereby the arrangement can be releasably connected to an alternating-voltage source.

11. An arrangement as claimed in claim 10, provided with plug-type hydraulic connection means for connecting the said coolant space to a coolant space of the alternating-voltage source.

12. An arrangement as claimed in any preceding claim, in combination with an alternating-voltage source, for example a transformer, connected electrically to the semiconductor components of the arrangement.

13. An arrangement as claimed in claim 12, having its coolant space in communication with a coolant space of the said alternating-voltage source.

14. A semiconductor arrangement, substantially as hereinbefore described with reference to Figures 1, 2*a* and 2*b*, or with reference to Figures 3*a*, 3*b* and 3*c*, or with reference to Figures 4*a* and 4*b*, or with reference to Figure 4*c*, of the accompanying drawings.

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1416561 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

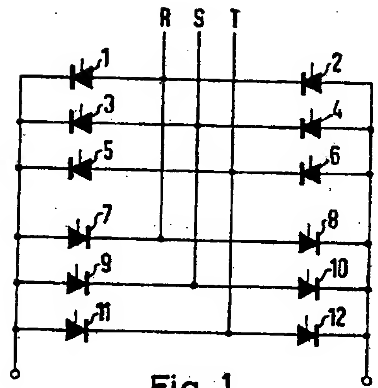

Fig. 1

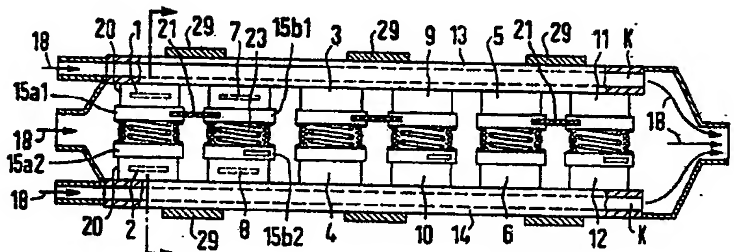

Fig.2a

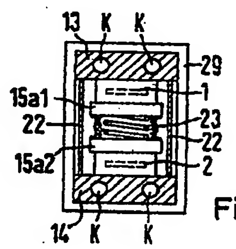

Fig.2b

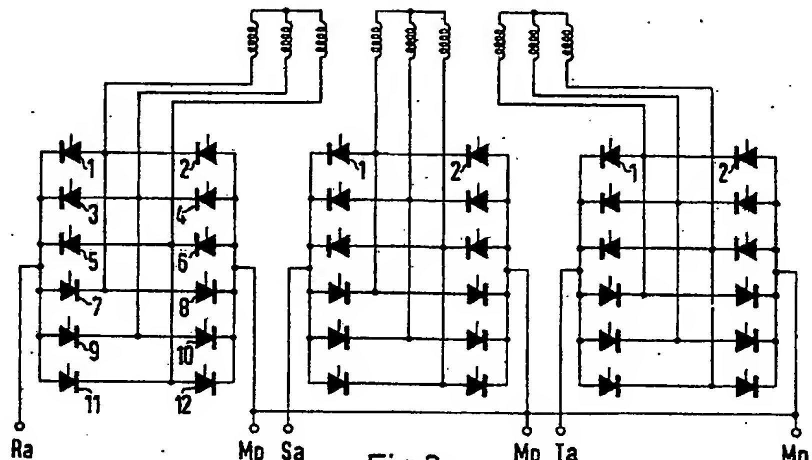

Fig.3a

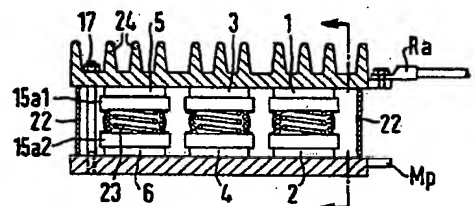

Fig.3b

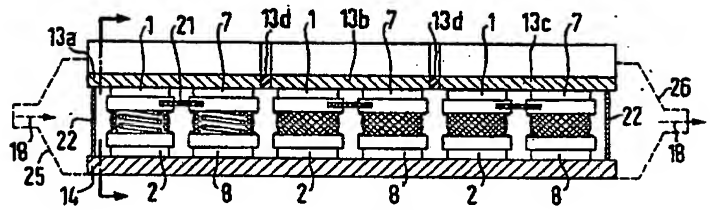

Fig.3c

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Sheet 3

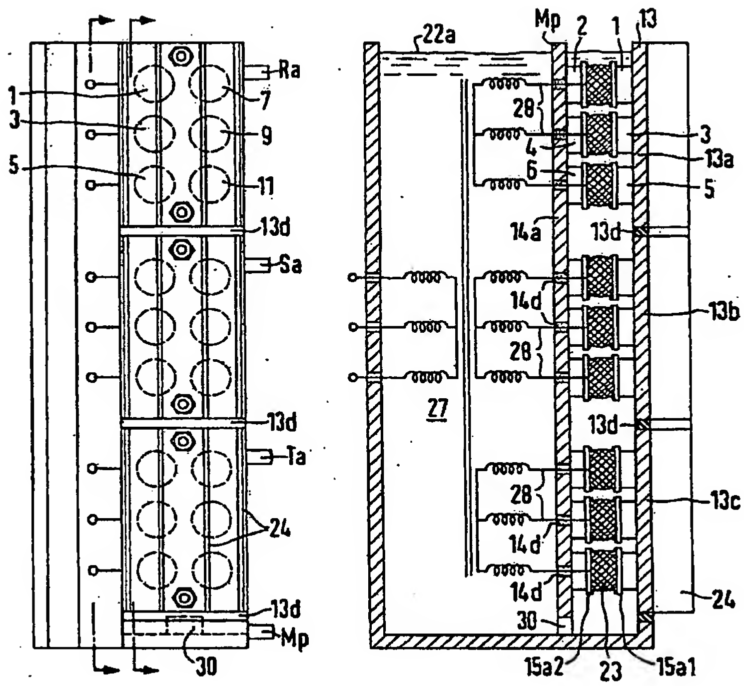

Fig.4b Fig.4a

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Sheet 4

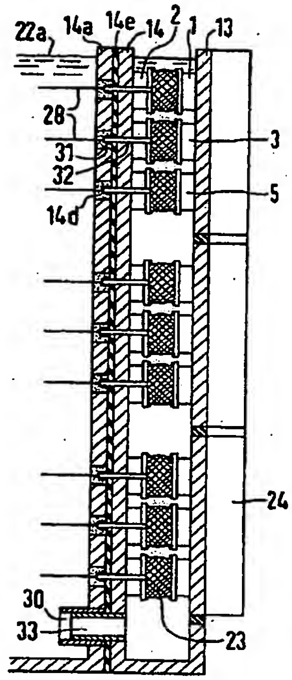

Fig.4c